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AN EXPERIMENTAL TEST OF A MODEL FOR DECISION STRATEGY SELECTION

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(Terence R. Mitchell and Lee Roy Beach, Investigators)

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Beach and Mitchell (1977) proposed a contingency model for the selection of decision strategies. The strategy that the decision maker sees as offering the greatest expected net gain is the one selected; i.e., selection is based on a cost-benefit analysis. Christensen-Szalanski and Beach (1977) formalized the strategy selection mechanism. The present paper reports on the tests of the major predictions of the formalized model.

The results strongly support the model's predictions (1) of the effect

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20. that fatigue and an increase in the value of making a correct decision will have upon the decision maker's confidence in the decision and the amount of time invested in making the decision, and (2) the assumption that strategy cost is an increasing function of perceived strategy selection.

In addition (3) a significant correlation was obtained between subjective certainty and obtained accuracy of the decisions, and (4) the value of making a correct decision was found to affect the complexity of the strategy selected to solve the decision.

The results suggest that people use a form of cost-benefit analysis as a basis for selecting decision strategies and that their behavior is optimal in that it tends to maximize the decision maker's expected net utility.

An Experimental Test of a Model for Decision Strategy Selection[1]

Beach and Mitchell (1977) have proposed a model to account for why decision makers do not always select normatively optimal strategies for solving decision problems. The model posits that the selection of a strategy is contingent upon characteristics of both the decision task and the decision maker and that the selection mechanism itself consists of a cost-benefit analysis: The strategy that appears to offer the greatest expected net gain is the one selected.

Christensen-Szalanski and Beach (1977) formalized the strategy selection mechanism and Figure 1 illustrates the hypothetical cost and benefit functions. The cost curve represents the cost to the decision maker, in time and energy, of using the various strategies. Because the cost ($\overline{U}_e$) of using a strategy is incurred after the strategy's selection but before the outcome of the decision is known, potential cost must be balanced against the potential benefits of using the strategy. It is assumed that the cost curve usually is an increasing function of strategy accuracy because a slight relative increase in strategy complexity may require a large absolute increase in demands upon the decision maker; strategy complexity is seen as linked to strategy accuracy.

For any given set of Decision Task Characteristics (Beach & Mitchell, 1977) there is associated with each strategy in the decision maker's repertory subjective probabilities that the strategy will lead to the correct decision, P_c, or to an incorrect decision, $1-P_c$. The utility of making the correct decision is designated U_c and the utility for making an incorrect decision is designated U_i.

For any strategy the product P_cU_c is the expected benefit if its use results in a correct decision and the product $(1-P_c)U_i$ is the expected benefit (positive or negative) if it results in an incorrect decision. Thus, the subjective expected benefit of a strategy is $P_cU_c + (1-P_c)U_i = P_c(U_c-U_i) + U_i$ which is the linear function illustrated in Figure 1.

Insert Figure 1 about here

For a specific decision task, the difference between the cost and the expected benefit line is the net expected gain from using a strategy that has that particular P_c of yielding a correct (accurate) decision. The decision maker should select the strategy associated with the P_c for which this difference is maximal, P_c^*. Graphically, P_c^* is at the point at which the space between the cost curve and the expected benefit line is widest. Intuitively, P_c^* is at the point at which the decision maker thinks he stands to make the most profit for the least cost.

Several predictions of behavior in different decision situations can be generated by varying the parameters of the cost and benefit functions. Figure 2a illustrates that as the value of making a correct decision (U_c) increases, the slope of the expected benefit line increases. As a result, P_c^* changes upward and the strategy with the corresponding P_c becomes the strategy of choice. Thus, the decision maker should both change strategies and be subjectively more confident that his or her decision is the correct decision as the value of making the correct decision (U_c) increases. Furthermore, because the cost curve is an increasing function of strategy accuracy, the decision maker also should use more costly strategies to make a decision under these circumstances.

Insert Figure 2 about here

By keeping the expected benefit line constant while changing the cost curve another prediction can be generated. Assuming that a fatigued decision maker must put more time and effort into the decision task with the consequence that

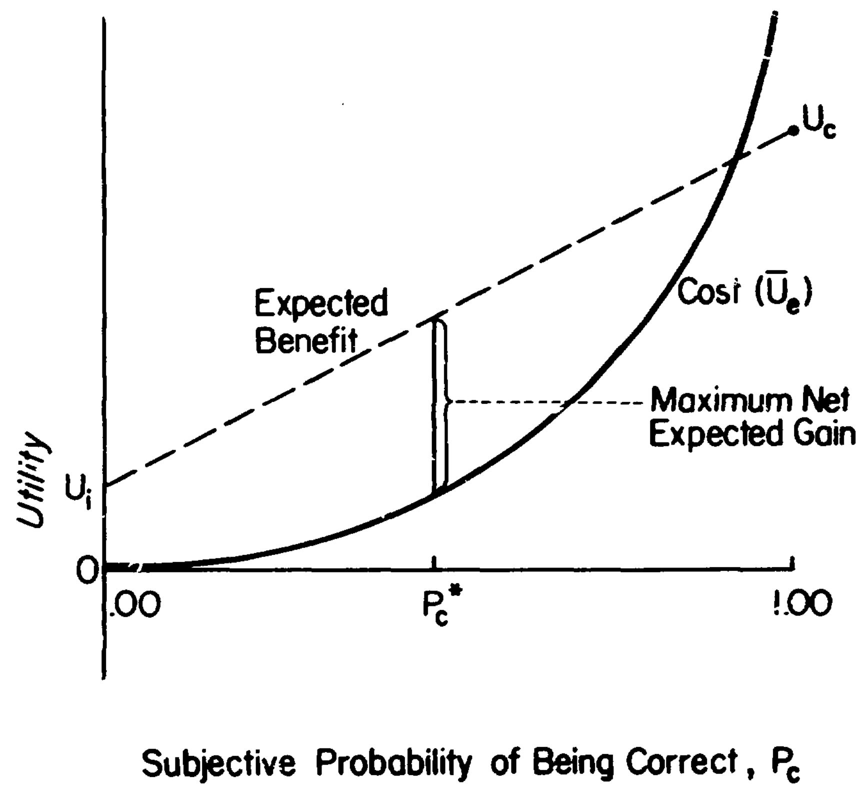

Figure 1. Hypothetical cost and benefit functions for various P_c.

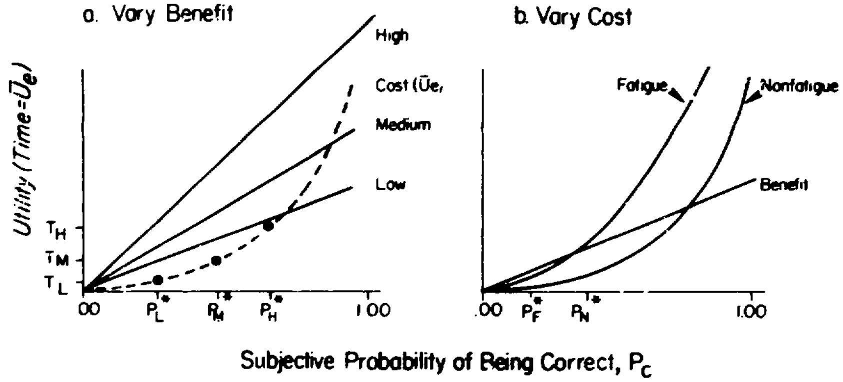

Figure 2. Hypothetical changes in P_C^* as a function of varying (a) benefit and (b) cost.

the cost curve rises (Figure 2b), the raised cost curve dictates a new strategy, one that is associated with a lower P_c^*. As a result, the decision maker should be less confident that his or her subsequent decision is correct.

The present experiment tests (1) the validity of the assumption that strategy cost is an increasing function of perceived strategy accuracy and the predictions that (2) fatigue and (3) an increase in the value of making a correct decision each influence behavior in the ways outlined above.

Method

Participants

Twelve students from the University of Washington business school participated for $9 each. An additional $15 could be earned by the participants depending upon their performance.

Procedure

Participants were required to give an estimate of the expected profits a hypothetical person might realize in a situation described in a written scenario (see Appendix for an example). All secnarios were constructed such that only three outcomes could possibly occur: One was very likely to occur ($.6 < p < .8$), one was very unlikely to occur ($p < .1$), and one would occasionally occur ($.2 < p < .35$).

Each scenario had a "correct profit" that could be calculated by using all of the available information; approximations to the correct answer could be obtained by relying on strategies that used part of the available information. Participants had to decide which one of the eight strategies listed in Table 1 to use to arrive at their estimate of the correct value. A measure of participants' confidence in their estimates was obtained by having them place intervals afound their estimates. Beach and Solack (1969) have found these "equivalence intervals" (EI) to be useful measures of a decision maker's confidence in answers to quantitative problems, the intervals are both easily understood by the decision maker and reliably reflect the decision maker's opinion about the accuracy of the answers. Equivalence intervals are conceptually very similar to statistical confidence intervals: as uncertainty increases the width of the equivalence interval increases. Furthermore, they have been shown to behave in rough accordance with the statistical properties of confidence intervals. Laestadius (1970) for example found that EI's for estimates of means from lists of numbers increased with an increase in the variance of the number on the list. Similarly, Beach, Beach, Carter and Barclay (1974) observed that the EI's for proportion estimates of binomial samples decreased as the sample size increased and the sample variance decreased. The participants were informed that the breadth of the interval determined the percentage of points that they earned for that decision and that the accumulated points could be used toward obtaining the $15 bonus at the conclusion of the experiment. They also were told that to earn any points from the decision the interval must contain the true value. However, the larger the interval the smaller the percentage of possible points they could earn for that decision.

Insert Table 1 about here

To test for the model's predictions of the shape of the cost curve, the time to solve each problem was used as an approximate measure of strategy cost to the participant. This was arranged by informing the participants that the bonus prizes would be allocated by rank of the subject's ratio of total points earned to the total time used. Participants were instructed to use as little time as possible while being as accurate as possible. This was done to encourage the subjects to maximize the rate at which points were earned.

Table 1

Possible Strategies for Solving Scenario Problems

1. Accurately calculate all three possible states of the world
2. Round and calculate all three possible states of the world
3. Accurately calculate the two most likely states of the world
4. Round and calculate the two most likely states of the world
5. Accurately calculate only the most likely state of the world
6. Round and calculate only the most likely state of the world
7. Guess
8. None of these

To test the model's predictions of the effect of the value of making a correct decision (U_c) each scenario for each participant was randomly assigned to one of five different pay scales that ranged from low (10) to medium (75, 150) to high (350, 500) numbers of points. These numbers of points were the upper limits that participants could earn for each problem; the actual percentage of points earned from each decision was determined by their confidence in their estimate (the size of the interval) and by the accuracy of their estimates. Accuracy was determined by calculating the absolute difference between their estimate and the true value. The participants were not informed either of the exact exchange rate between confidence and the percentage of points earned, or between accuracy and the percentage of points earned. They were only informed that an increase in interval size and a decrease in accuracy would reduce the percentage of points earned. At the conclusion of the experiment, 10% of the maximum possible points for each problem would be deducted for every 1,000 units in the subject's confidence interval and for every 500 units difference between the subject's estimate and the true answer. The sum of the points they earned for all decisions would then be divided by the total time they used to solve the decisions to determine their ranking for the bonus prize.

Following the completion of these instructions each of the eight strategies was explained by using it to arrive at the solution of a sample problem. The participants were then given up to 15 minutes to review the instructions and materials that had been presented up to that time and were allowed to explore the probable accuracy and time requirements of the eight strategies. When they were satisfied that they understood the task and the strategies they were permitted to begin the experiment.

Sessions were run on two consecutive days. On each day participants were required to arrive at a decision on 10 of the 20 scenarios. One scenario of each point value was presented in each half of the session. The procedure for both days was identical with the exception that before one of the sessions began, subjects were required to search for randomly generated "target" numbers in a series of random number tables. This task lasted for 40 minutes and was used to create a state of mental fatigue in the participants without altering their mathematical abilities. Half of the participants received the stimulus the first and half received it the second day.

Results and Discussion

Effect of the Value of the Decision on Confidence and Time

A Hollander (1967) one-way non-parametric analysis of variance was used to analyze both the confidence data (inverse of interval size) and time data used by each subject at each pay scale. This test not only examines whether the samples could have originated from the same population but also examines whether there are any differences in an *a priori* specified order. As Figures 3a and 3b illustrate, the data for the confidence and time measures are clearly significant and in the predicted order (confidence: $z = 3.66$, $p < .001$; time: $z = 6.36$, $p < .001$).

Insert Figure 3 about here

Effect of Fatigue on Confidence

A Wilcoxon signed rank test was used to analyze confidence data for each pay scale of the session that followed the random number task with the session which was not preceded by that task. The difference was not significant ($z = -.47$, $p = .82$). A manipulation check revealed failure of the task to produce fatigue; only two subjects reported that the random number task was fatiguing.

A second approach to fatigue was to compare the data from the first half of each of the two sessions with those of the second half. All participants reported that they felt more mentally fatigued after each three hour session than when they began. When these two sets of data were analyzed with the Wilcoxon signed rank test, the results were significant in the predicted direction (Figures 4a and 4b; $z = 1.88$, $p = .03$, one-tailed test).

Insert Figure 4 about here

Since this comparison is based on an ABAB design it is possible that experimental practice effects and not fatigue account for the trend. If this were so the results would imply that people are less certain of their answer as a result of more practice. Not only is this illogical, a Wilcoxon signed rank test of the first fatigue period compared to the second non-fatigue period fails to show any practice effects and supports the earlier interpretation ($z = -.94$, $p = .83$).

Cost Functions and the Effect of Fatigue

As Figure 2a illustrates, the psychological cost curve can be mapped by varying the expected benefit lines and fitting a curve to the points with coordinates (P^*_L, T_L), (P^*_M, T_M), (P^*_H, T_H), etc.; the best fit power curves through the points associated with the mean group confidence and time used for each pay scale for both the fatigue and non-fatigue conditions. Figure 5 shows these power curves. Assuming an interval scale of confidence both of the cost curves are curvilinear with exponents significantly greater than 1.0 (Normal: $s_b = .007$, $t = 81.59$, $df = 3$, $p < .001$, $k = 100580873$, Fatigue: $s_b = .026$, $t = 25.22$, $df = 3$, $p < .001$, $k = 224529562$). Furthermore, the fatigue (cost) curve accelerates faster than the non-fatigue cost curve. This trend, with only six

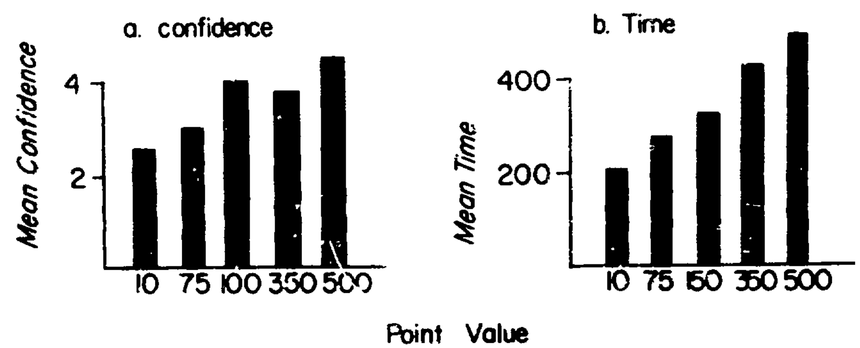

Figure 3. The effect of point value of the correct decision upon (a) mean confidence in accuracy and (b) mean time used.

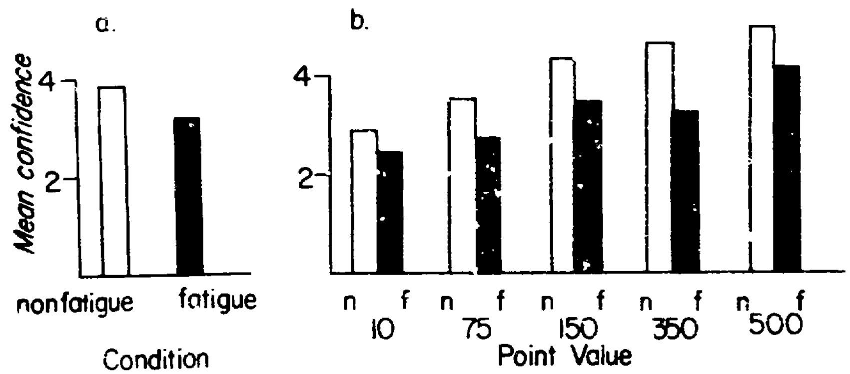

Figure 4. The effect of fatigue upon mean confidence in accuracy for (a) fatigue and nonfatigue conditions and (b) point values of correct solutions.

degrees of freedom and using time as an approximation of cost is significant at the p = .09 level (s_{f-n} = .045, t = 1.511).

Insert Figure 5 about here

Effect of the Decision Value on Strategy Complexity

Beach and Mitchell (1977) suggest that in western cultures most people believe that the more thoroughly and systematically one approaches a decision the greater the chance of being correct. This would imply that more thorough and complex strategies would be used for more valuable decisions. A Hollander Anova was used to analyze the complexity of the strategies used for each pay scale. The eight strategies in Table 1 can be assigned 3, 2, 1, or 0, depending upon whether they required the use of 3, 2, 1, or 0 (guess) pieces of information to solve for the solution. (Only two subjects reported using "none of these" and in all four instances the strategies were described as a combination of accurately calculating three factors and rounding three factors: They received a 3.) Figure 6 shows that significantly more complex strategies tended to be used to calculate more valuable decisions (z = 5.62, p < .001). Although this relationship is not predicted by the Christensen-Szalanski and Beach (1977) formulation, its presence suggests that for quantitative problems of the variety used here the Beach and Mitchell (1977) suggestion is valid.

Insert Figure 6 about here

Subjective Calibration of Uncertainty

To compare whether subjects were consistent in assessing their uncertainty, as determined by the size of their interval, a Spearman rank order correlation was used to compare the group's mean interval size for each of the five pay scales with the mean accuracy (inverse of the absolute distance of the subject's point estimate from the true value). Figure 7 illustrates the significant correlation between subjective certainty and obtained accuracy.

Insert Figure 7 about here

Conclusion

Christensen-Szalanski and Beach (1977) made several predictions of a decision maker's behavior. All of those predictions tested in this experiment have been supported. This suggests that people use a form of cost-benefit analysis as a basis for selecting decision strategies and that their behavior is optimal in that it tends to maximize the decision maker's expected net utility.

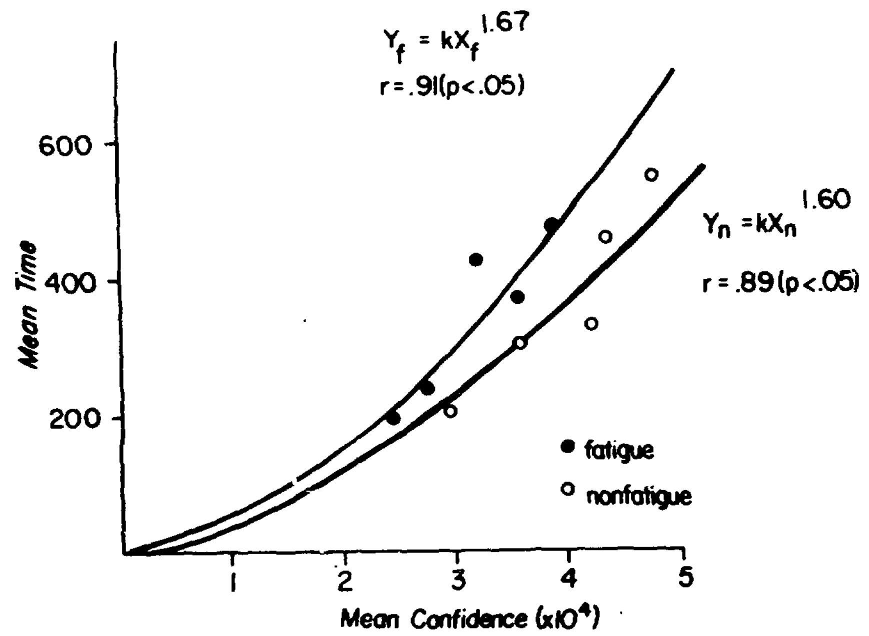

Figure 5. Best fit power functions for mean confidence and mean solution time for fatigue and nonfatigue conditions.

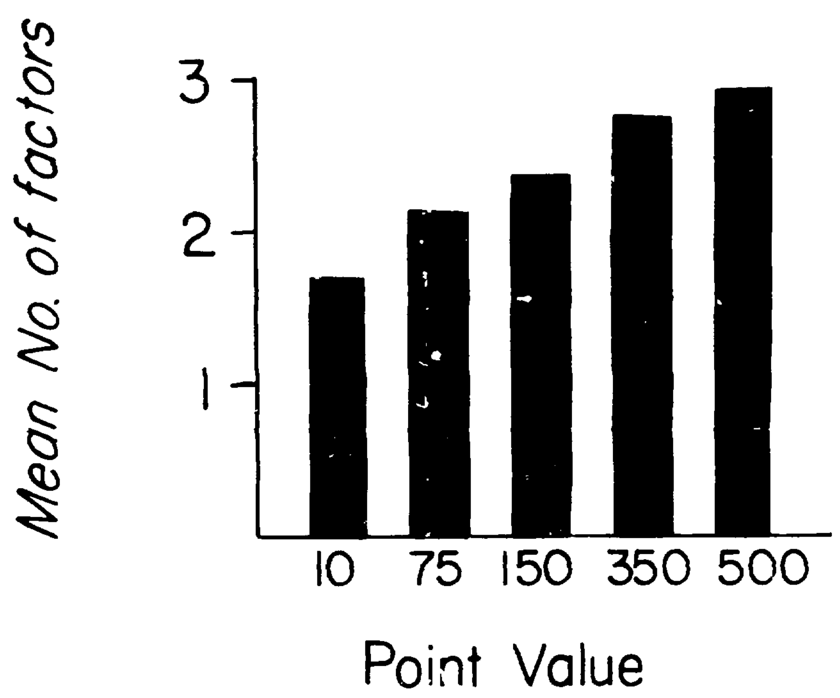

Figure 6. Effect of point values of correct solutions on complexity of chosen strategy (i.e., amount of information used).

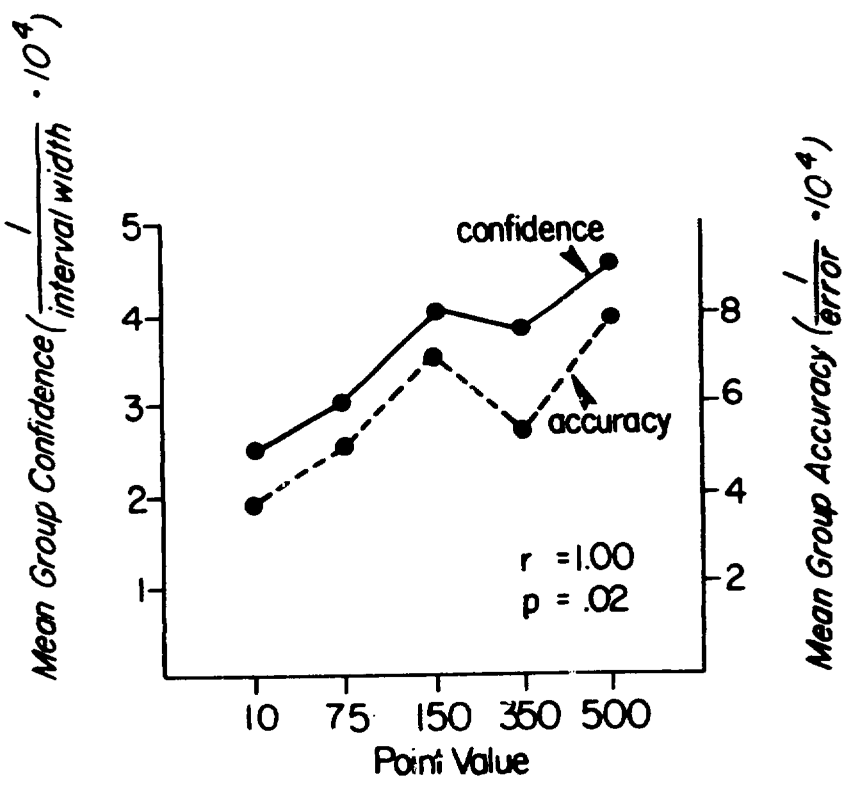

Figure 7. Mean confidence in accuracy of solutions and observed accuracy as functions of point values of c rect solutions.

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Footnotes

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Appendix 1

Sample of Scenarios Presented to Subjects

Because of past trends an investor believes that his gains from stocks on the stock exchange will depend upon whether the banks raise their lending rate. There is a 62% chance of the banks lowering their lending rate from its present value, a 31% chance of the banks keeping the same lending rate, and a 7% chance that they will increase their lending rate.

If the lending rate goes down there is a 71% chance of earning $27,752, a 23% chance of earning $16,389, and a 6% chance of earning $2,477.

If the lending rate remains the same there is a 28% chance of earning $27,752, a 56% chance of earning $16,389, and a 16% chance of earning $2,477.

If the lending rate increases there is a 14% chance of earning $27,752, a 19% chance of earning $16,389, and a 67% chance of earning $2,477.

What is the investor's expected profit? ____________________

What are your upper and lower estimates? ______________ to ______________

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